

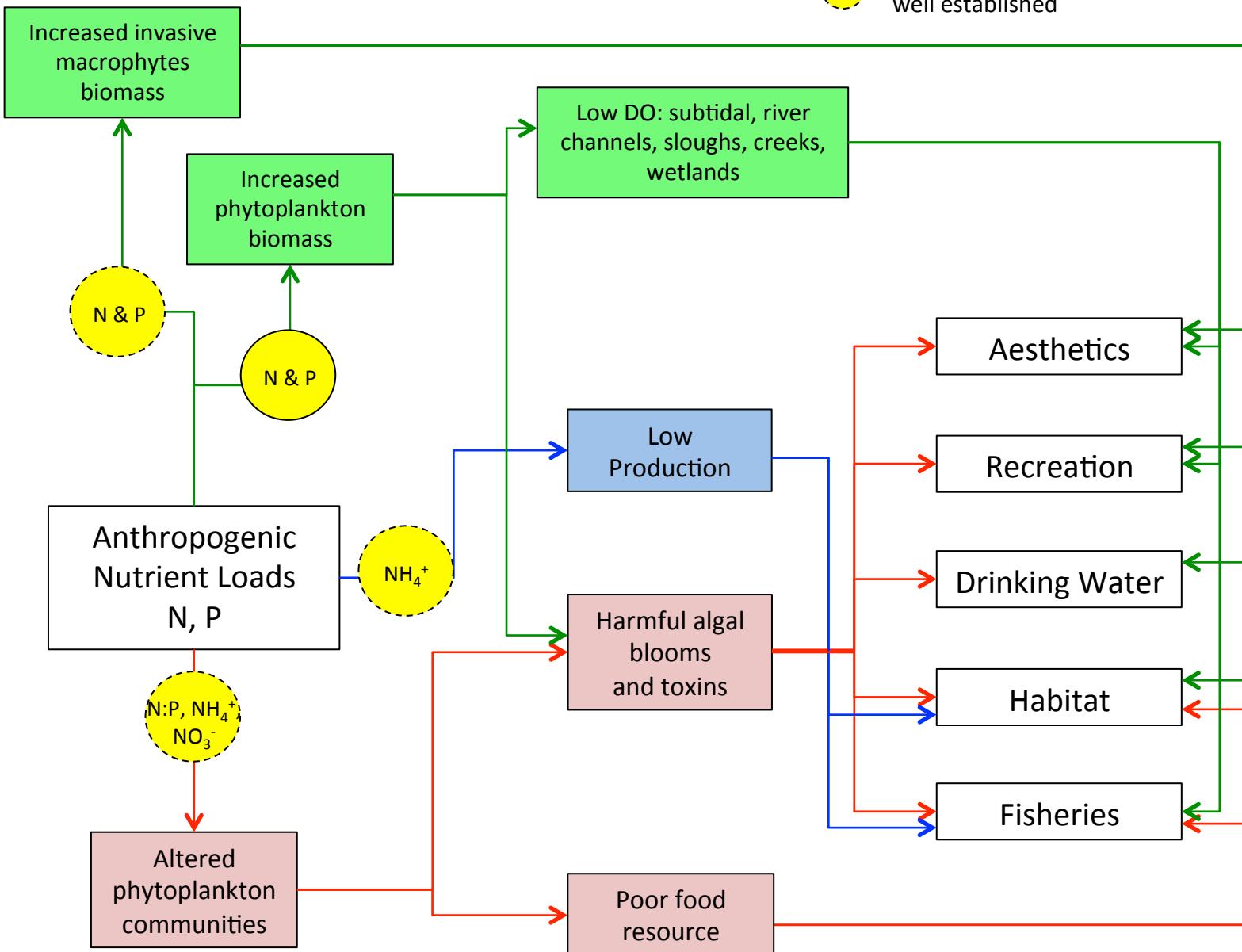
Status and Trends of Nutrient and Phytoplankton Biomass in the Delta

- Overview of system, Background
- Nutrients: Loads, Transformations, Changes over time
- Changes in phytoplankton biomass, productivity
- Changes in phytoplankton community?

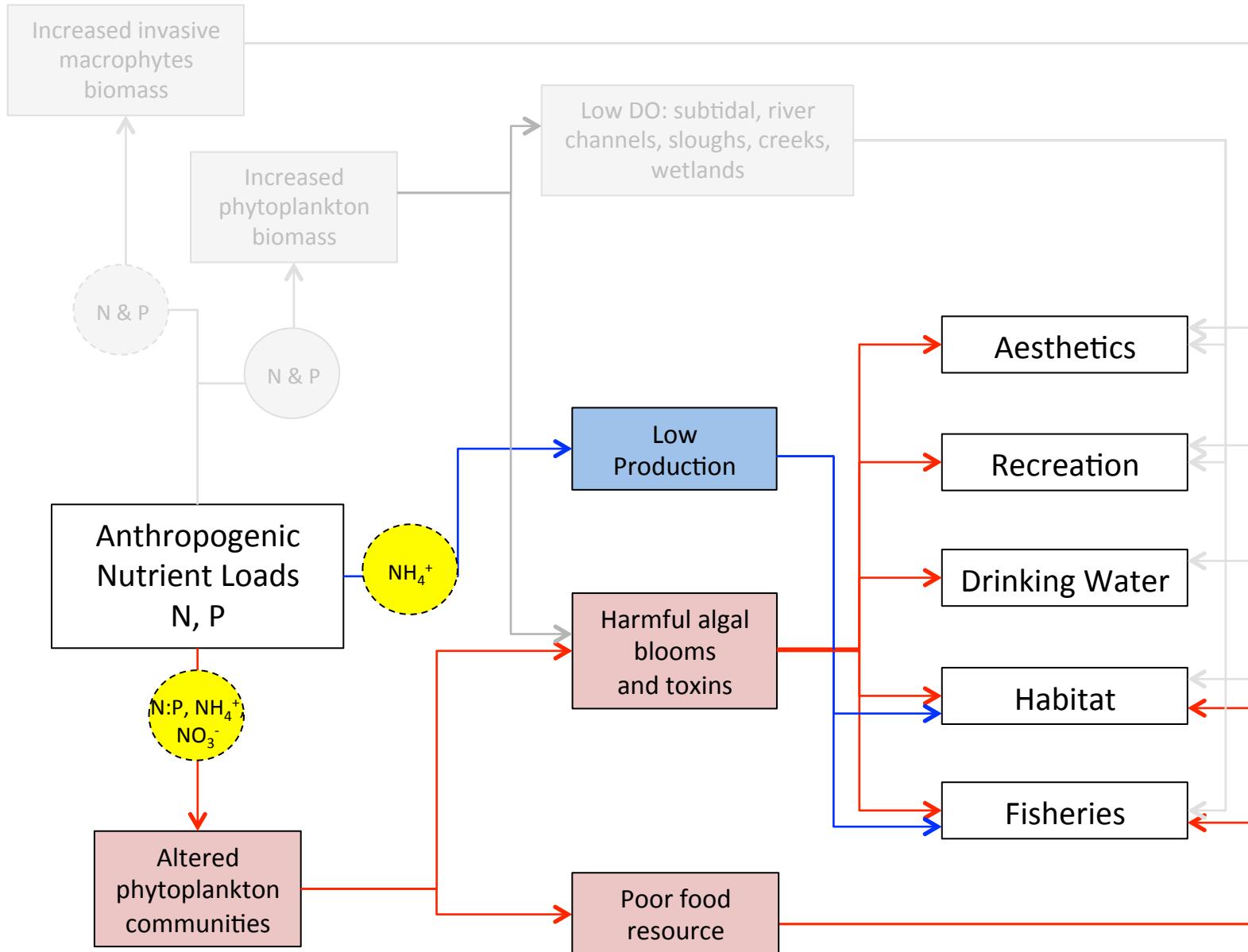
David Senn
November 29 2016

Adverse Impact Pathways: Nutrient-Related

- Mechanistic link well-established in estuarine and freshwater ecosystems
- Hypothesized mechanistic link: uncertain or not well established



NH₄-Paradox and Ecological Stoichiometry Hypotheses

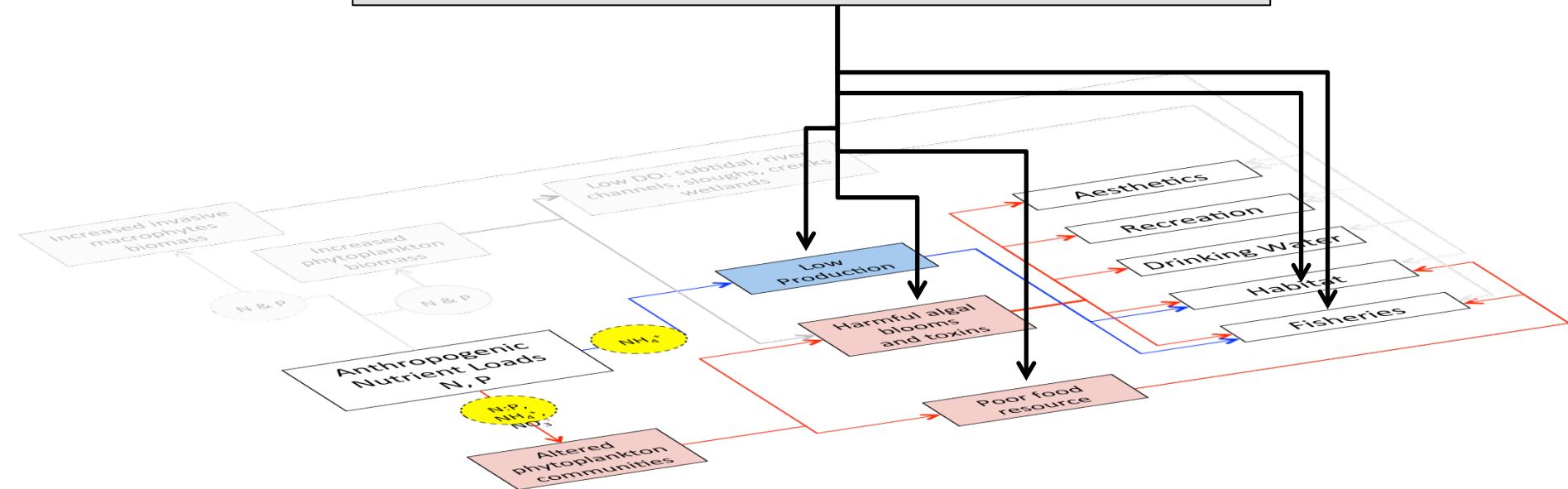


Multiple stressors influence phytoplankton biomass, food supply and quality, and habitat

NAS 2012

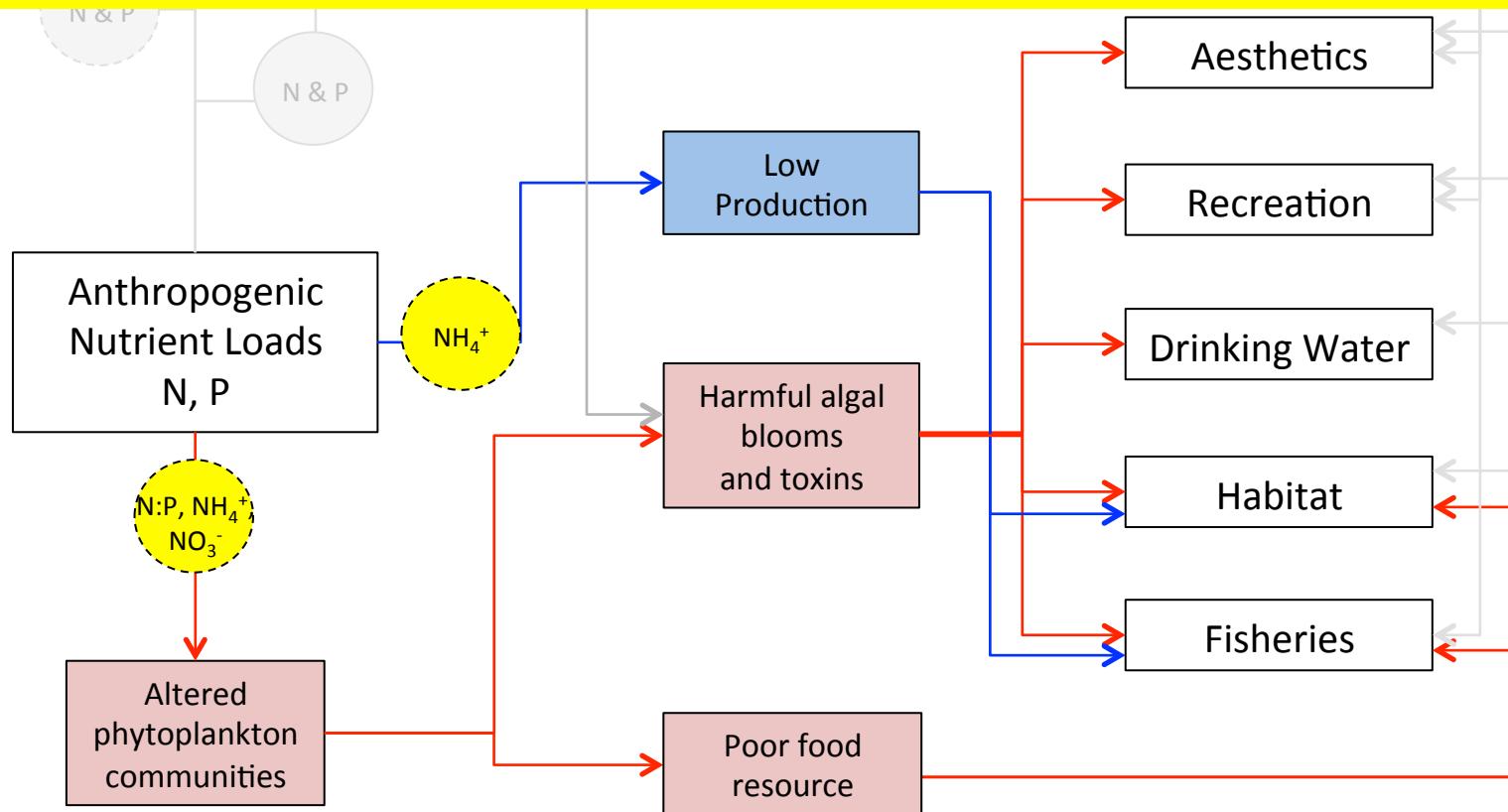
Overarching science/management question: Relative roles of nutrient pathways alongside other stressors?

- Light levels
- Temperature
- Turbulence/mixing
- Grazers, invasives
- Habitat alterations
- Flow withdrawals
- Contaminants/pesticides



Workshop Goals (among others): Inform next steps related to NH₄-paradox and ecological stoichiometry hypotheses

1. What are the areas of scientific agreement?
2. What are the (specific) areas of disagreement? e.g., mechanisms (physiology), relative importance
3. Recommendations for next steps? hypothesis testing / quantify mechanisms



Suisun Synthesis I

Suisun Bay Ammonium Synthesis Report

Executive Summary

- 2. Lit Review: Phytoplankton Utilization/Growth on NH₄ vs. NO₃ (*Berg*)
- 3. Review of NH₄-inhibition studies (*Senn and Jabusch*)
- 6. Nutrient loads/concentrations/cycling in Suisun Bay (*Novick and Senn*)



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SFEI 2014b

Suisun Synthesis II

Nutrient Forms & Ratios: Varying technical perspectives

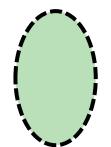
- 2. Overview of Ecological Stoichiometry in Delta-Suisun (*Glibert*)
- 3. Overview of Ammonium Paradox (*Dugdale et al.*)
- 4. Lit Review: Influence of nutrient forms/ratios on phytoplankton growth and community (*Berg*)
- 5. Phytoplankton community shift? (*Senn*)
- 6. Exploring nutrients vs. multi-stressor hypotheses (*Cloern et al*)



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SFEI 2015

Important Features of the Delta



Yolo Bypass
Cache Slough Complex



WWTP nutrient
point sources



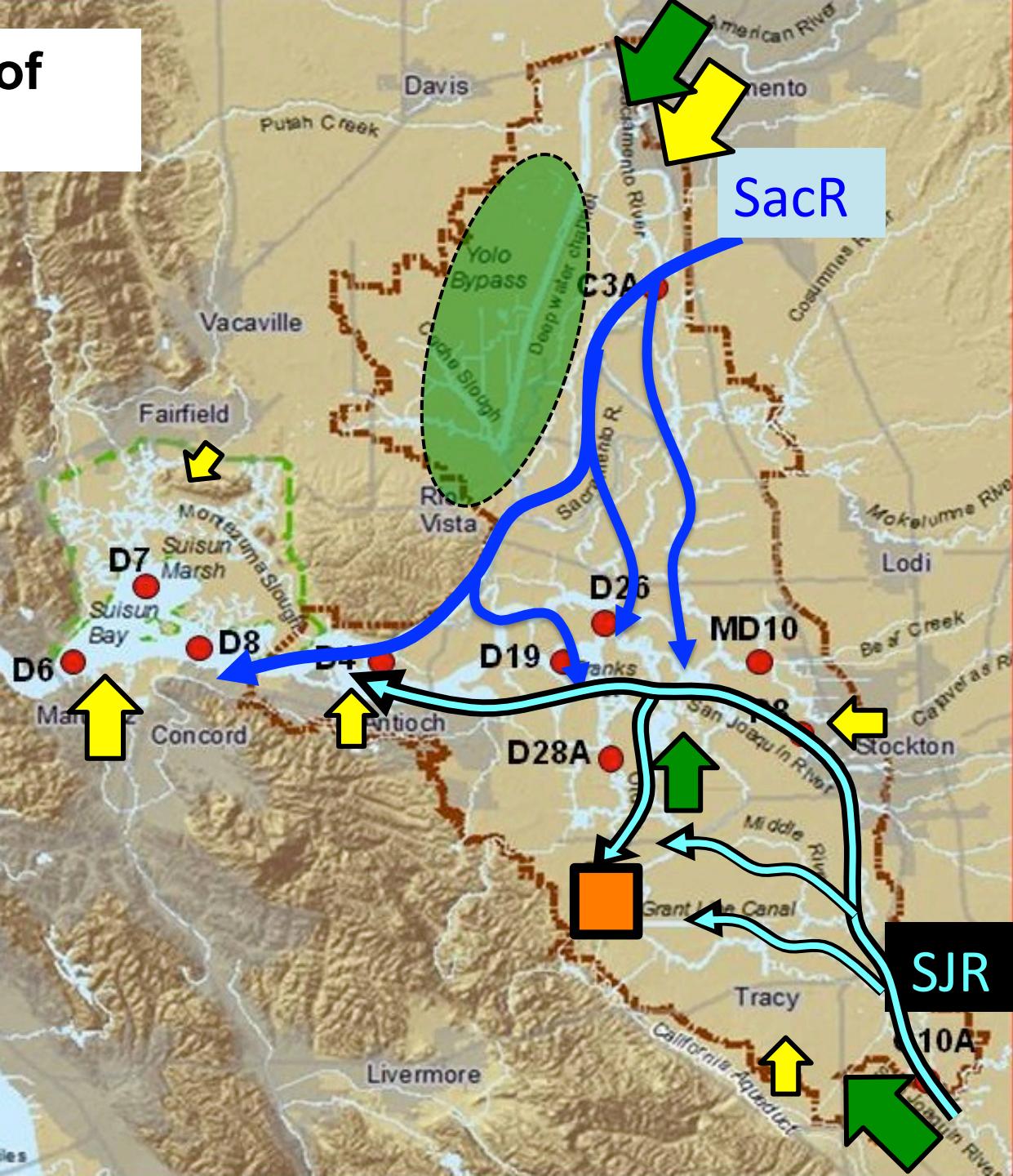
Ag nutrient inputs



Export Pumps



DWR-EMP
monitoring stations

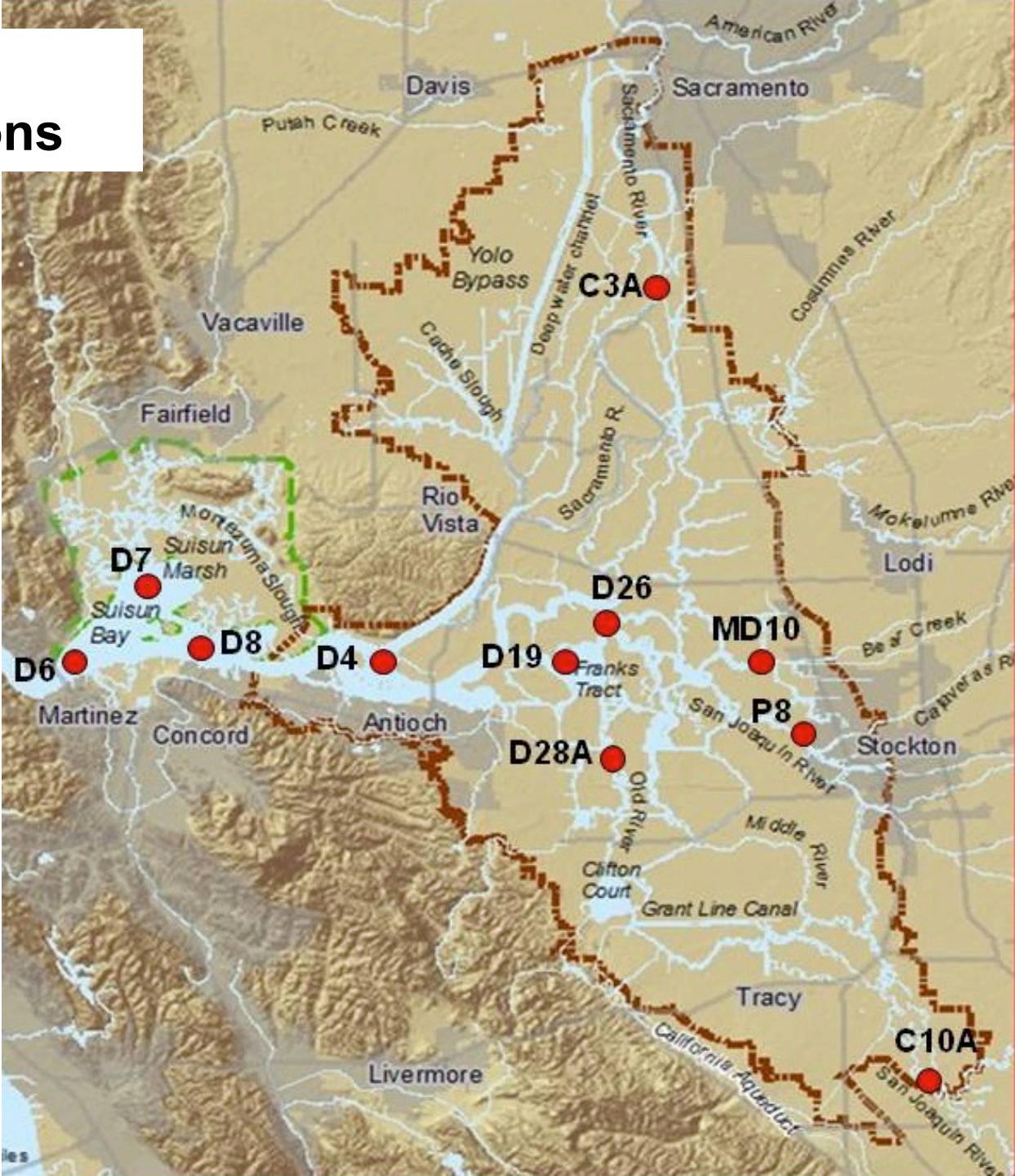


DWR-EMP Discrete Water Quality Stations

1975-present

Nutrients and nutrient-related

- Ammonia
- Nitrite-Nitrate
- Organic Nitrogen or Total Kjeldahl Nitrogen
- Ortho-Phosphate, TP
- Chlorophyll a
- Phaeophytin
- Silicate
- Dissolved Oxygen
- Temperature
- Suspended particulate matter
- Phytoplankton community **



DWR-EMP
monitoring stations

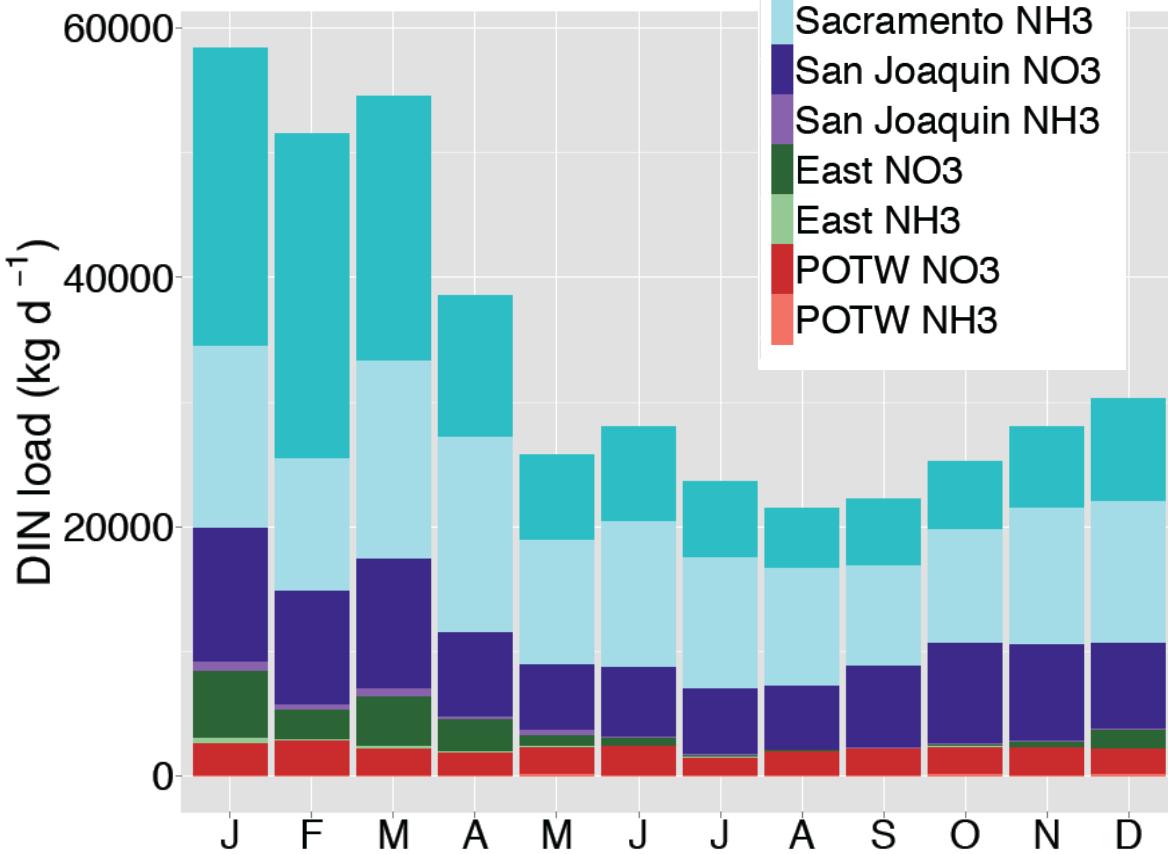
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Nutrient loads to the Delta

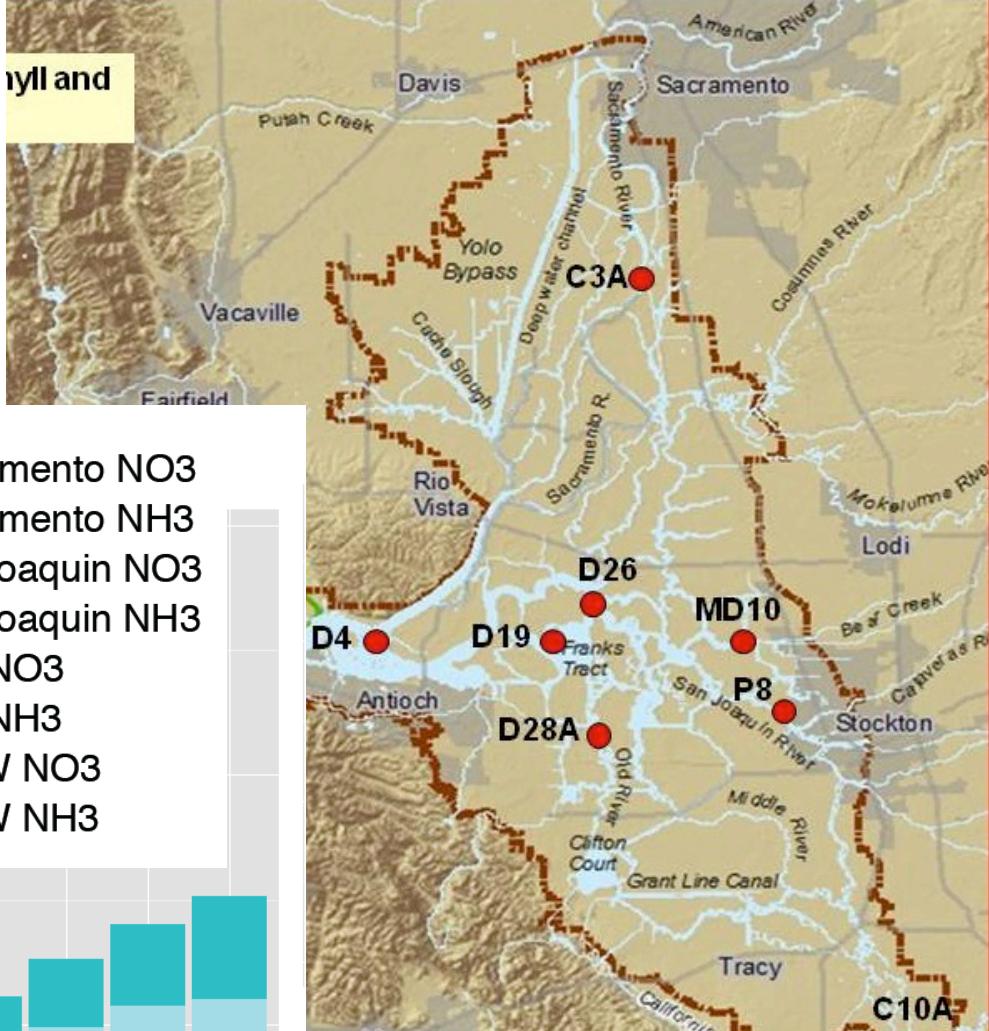
- Delta receives large nutrient loads
- Strong seasonal variability

$$\text{DIN} = \text{NO}_3 + \text{NO}_2 + \text{NH}_4$$

2006-2011



SFEI 2015



- Major load changes ahead: both total and form
- System “machinery” also changing:
 - light, grazers, T (?)

NH₄ Loads from Regional San

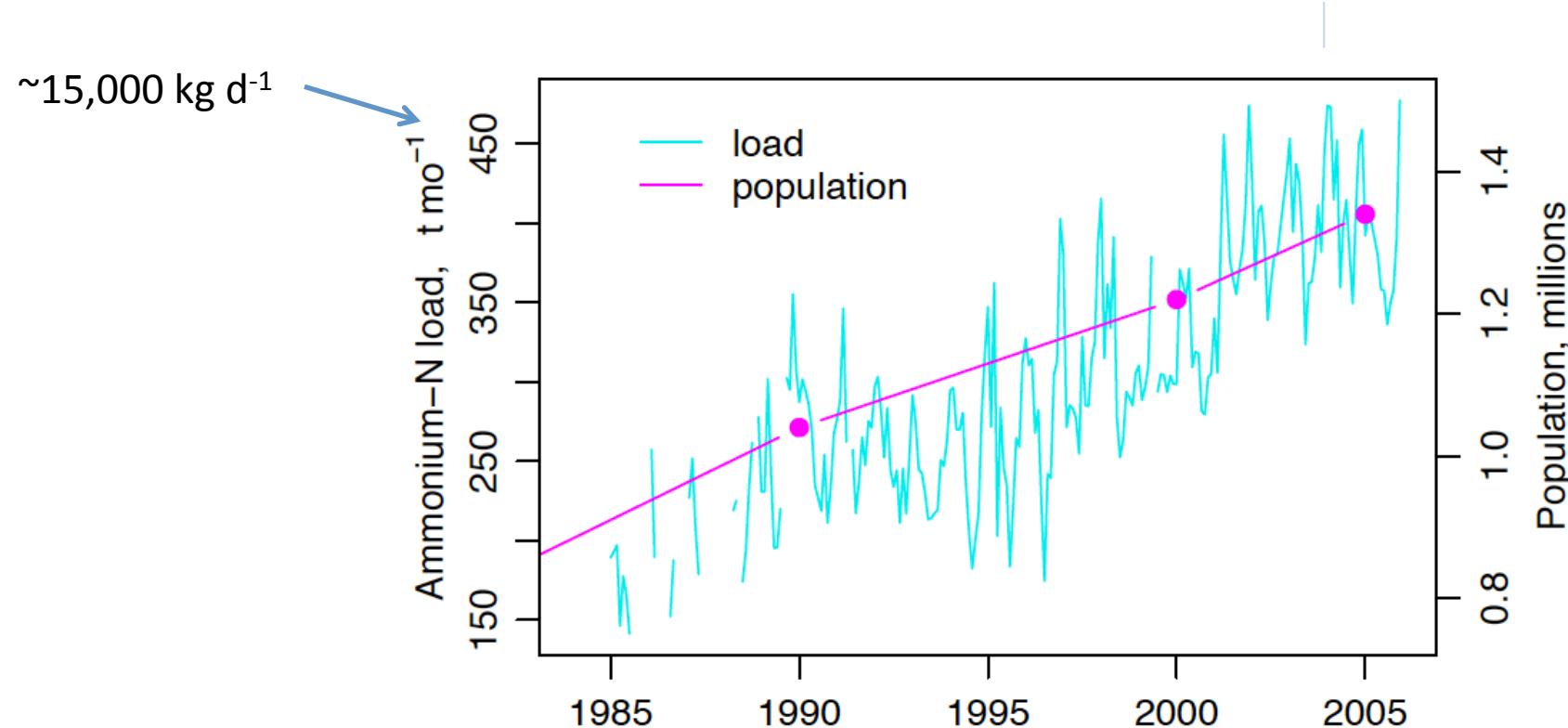


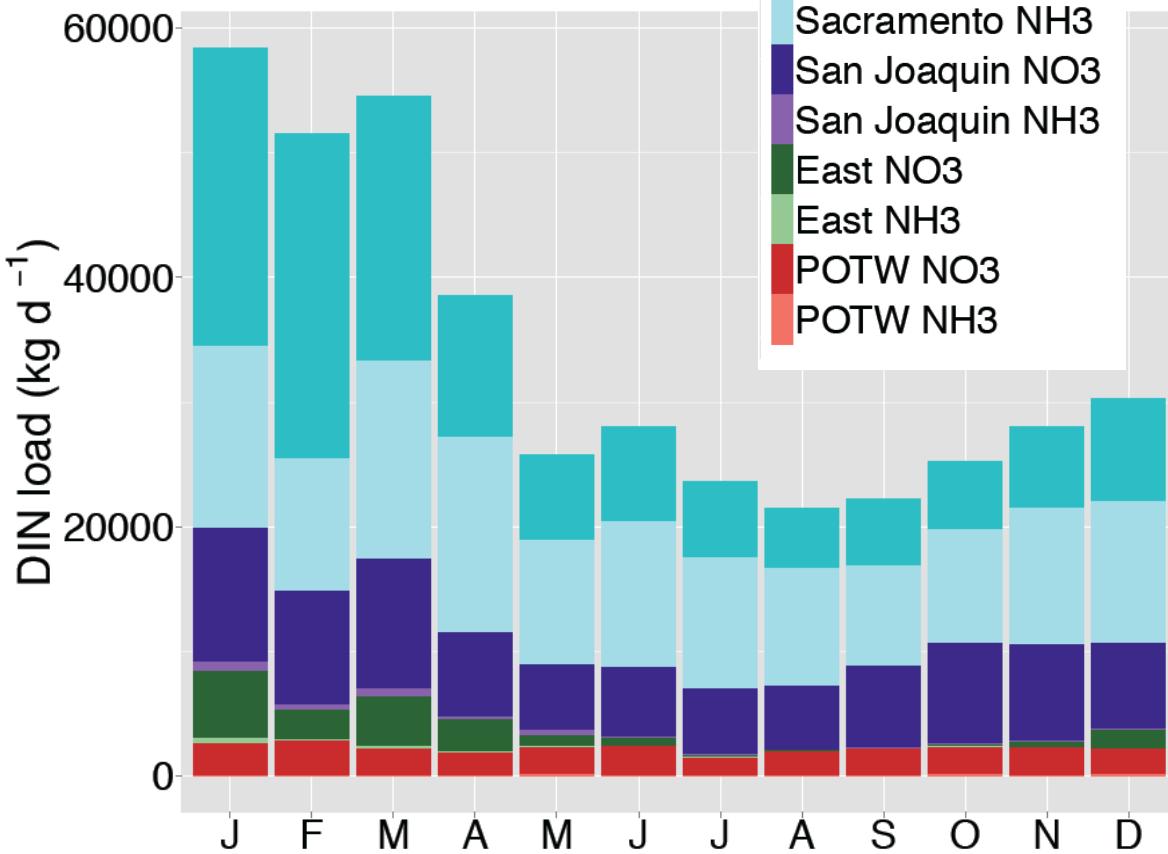
Figure 15. Monthly load of ammonium-N in wastewater from the County of Sacramento Regional Wastewater Treatment Plant. County population is also shown for comparison.

Nutrient loads to the Delta

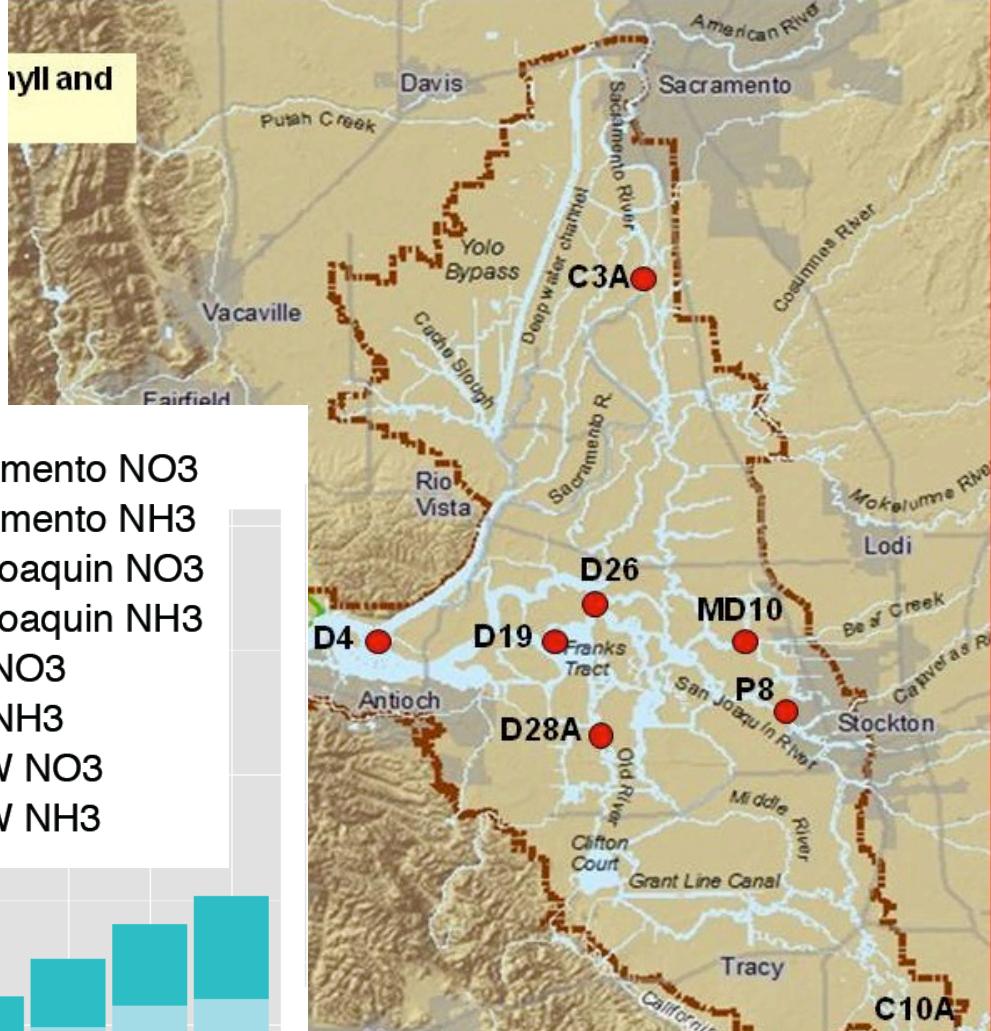
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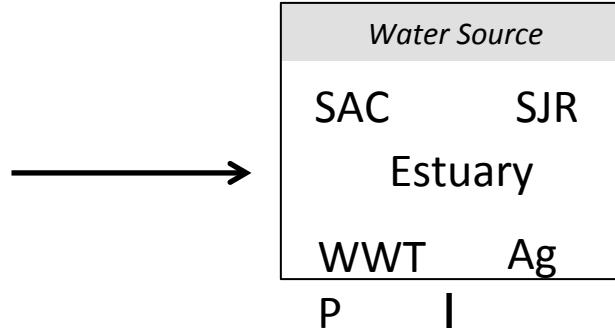
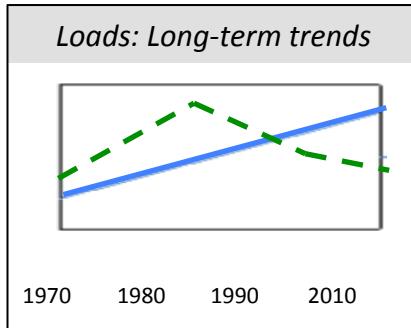
2006-2011



SFEI 2015



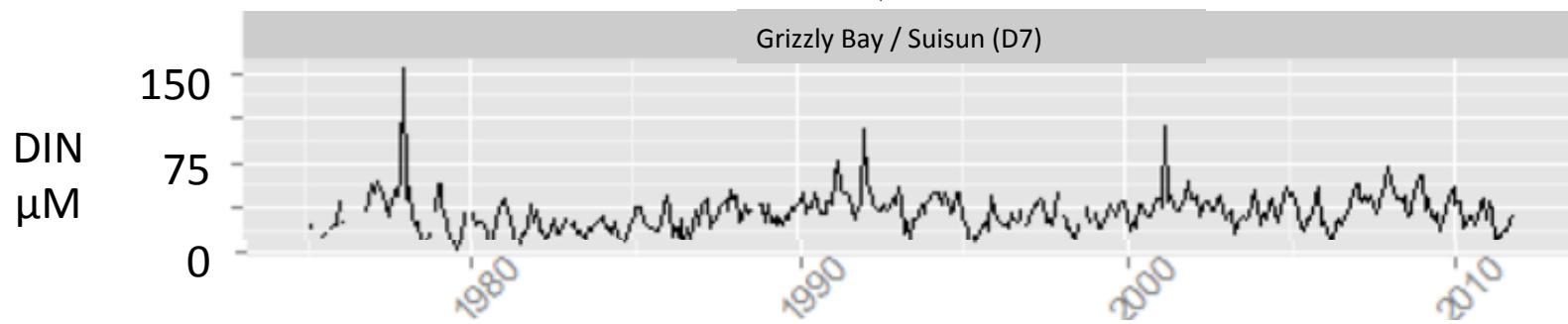
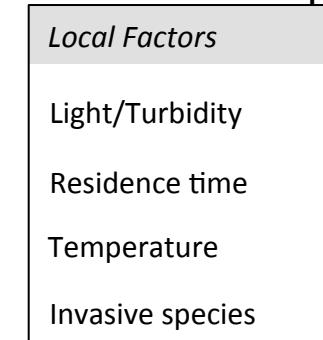
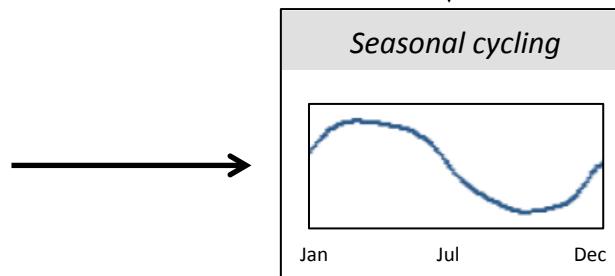
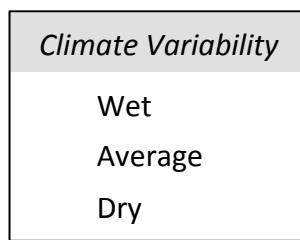
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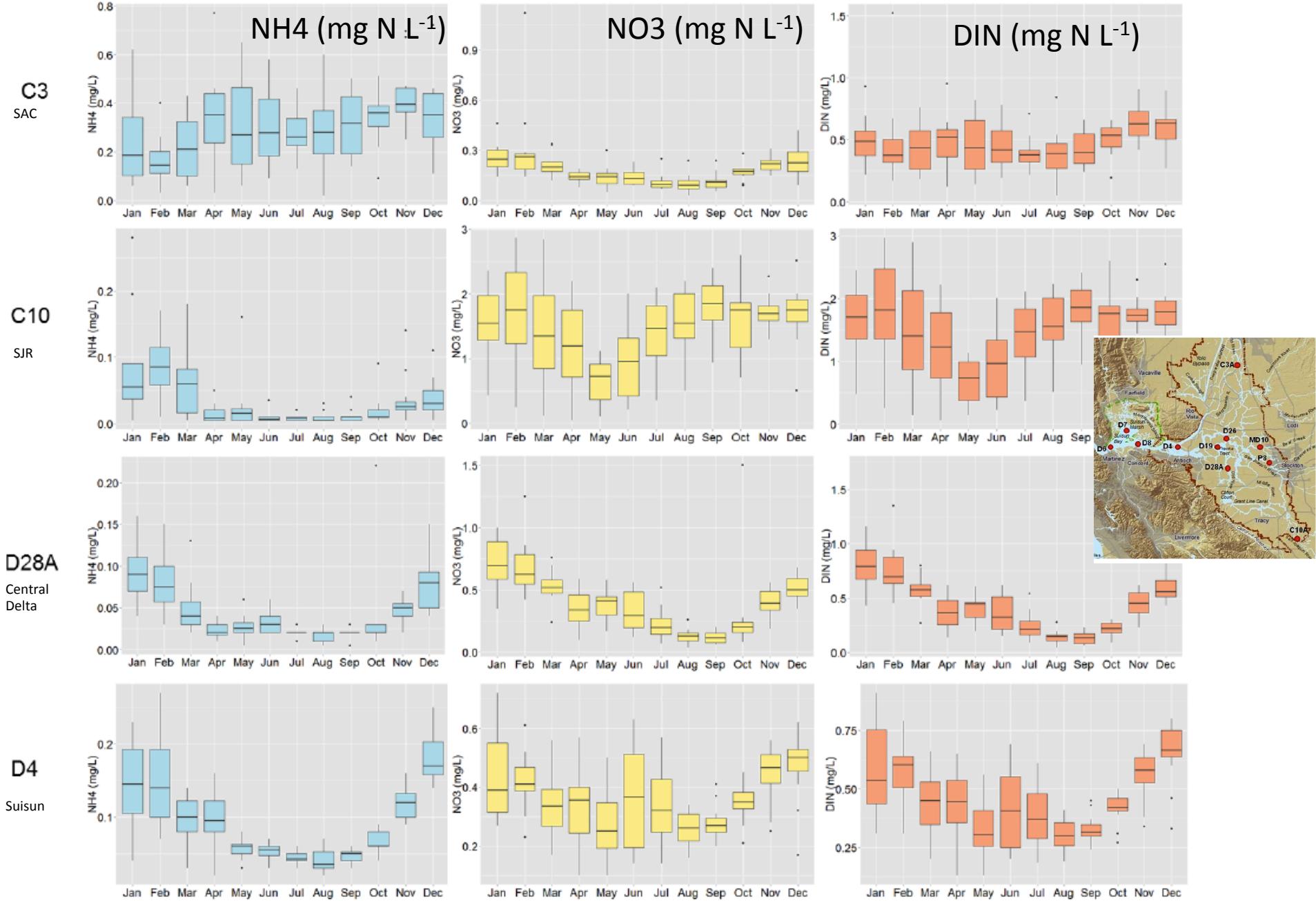
[DIN] change over time?

What caused the changes?

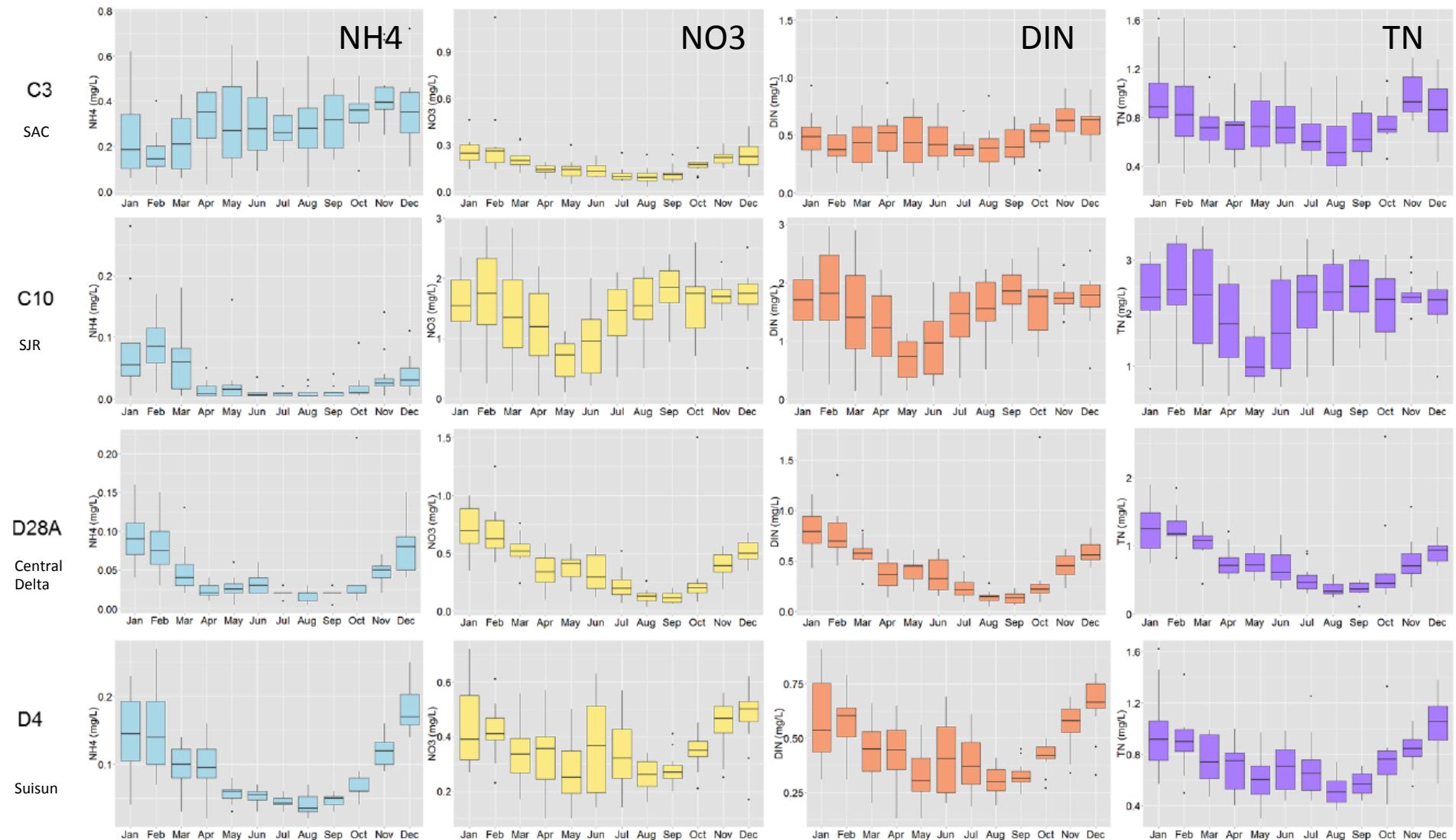
Can we anticipate how future management actions will play out?



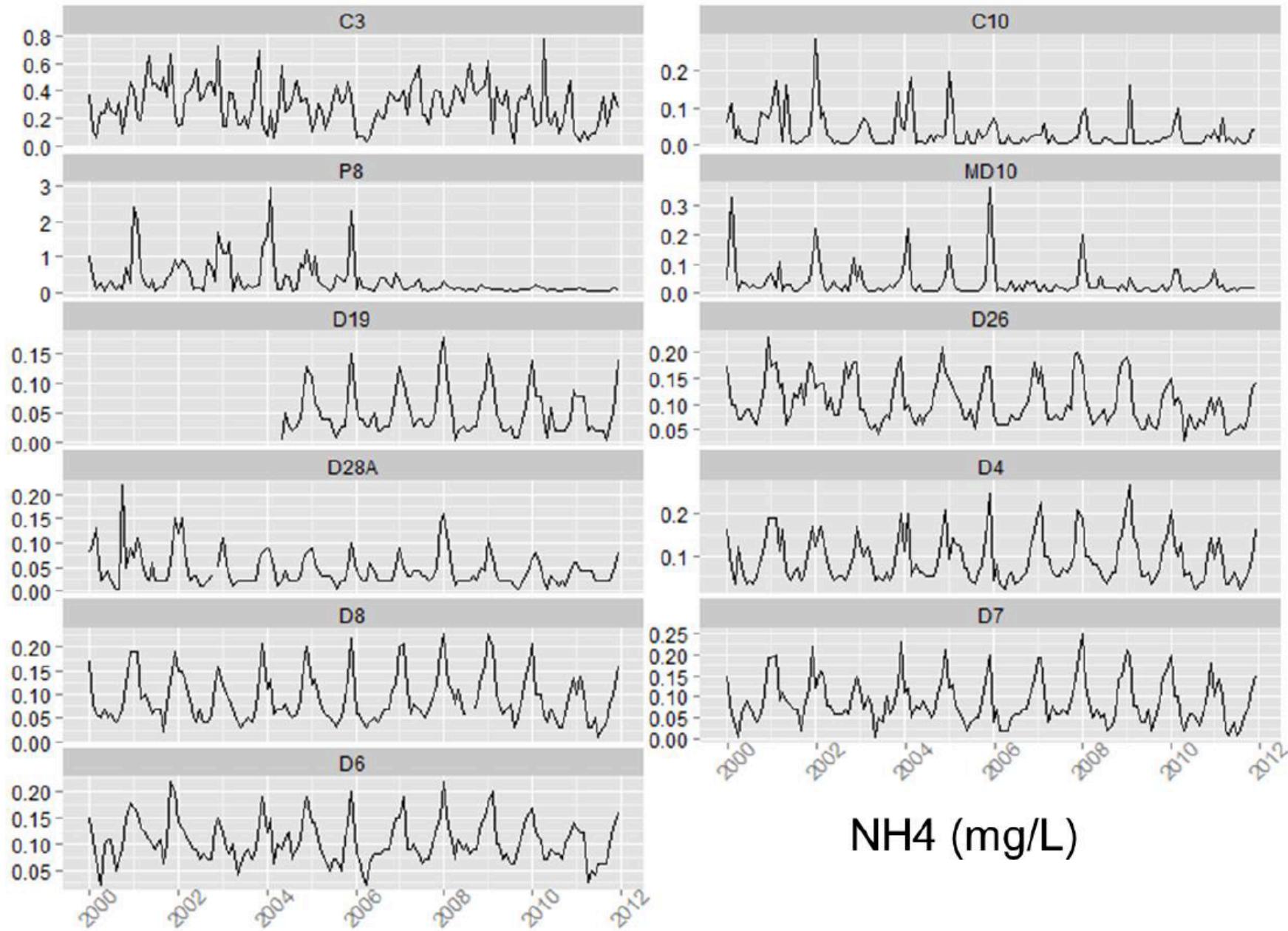
DWR-EMP 2000-2011 Data (subset of stations)



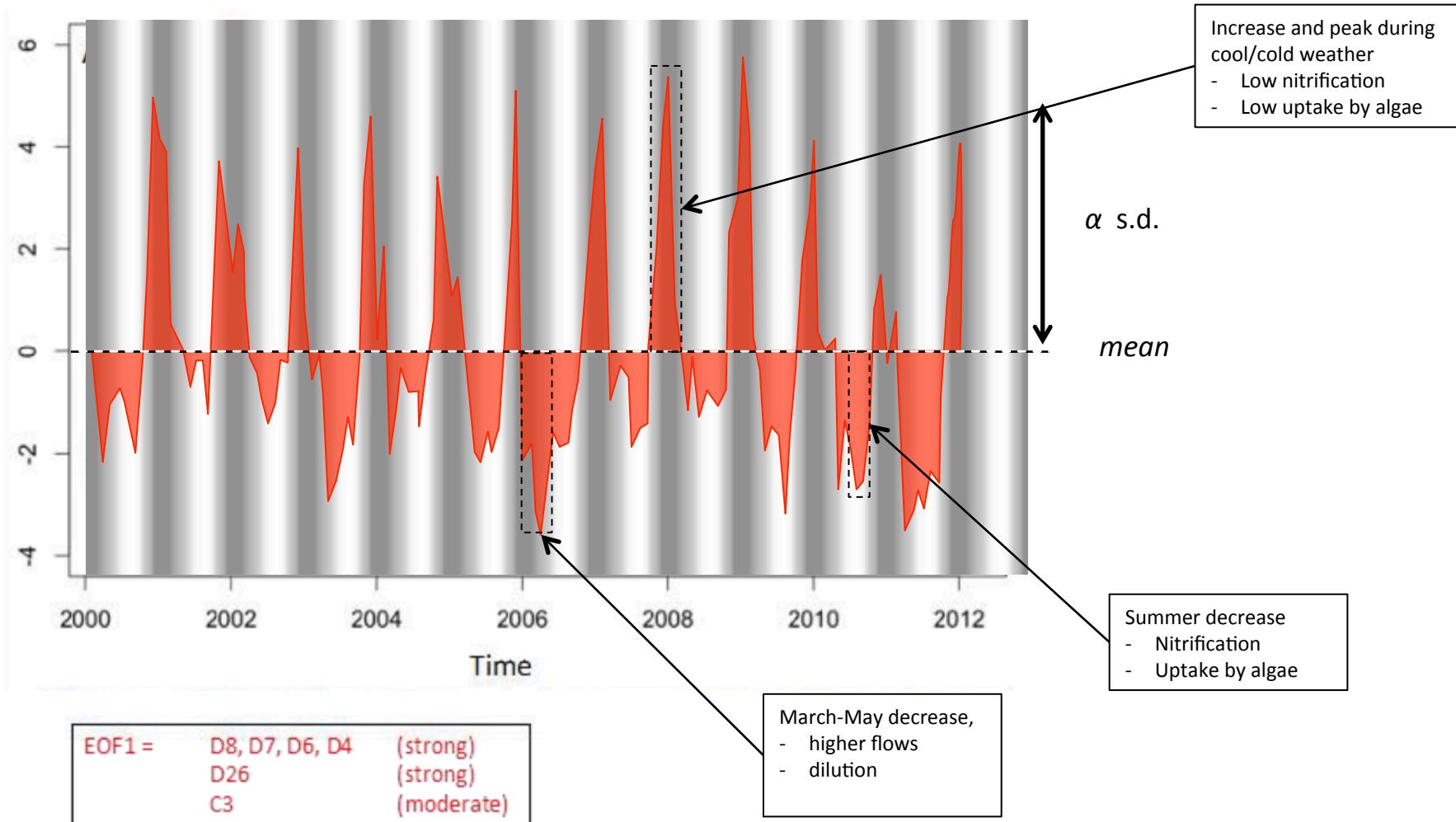
DWR-EMP 2000-2011 Data (subset of stations) (mg N / L)



Dominant processes controlling N concentration and fate?



Dominant 'modes' of seasonal variations in NH4 concentration



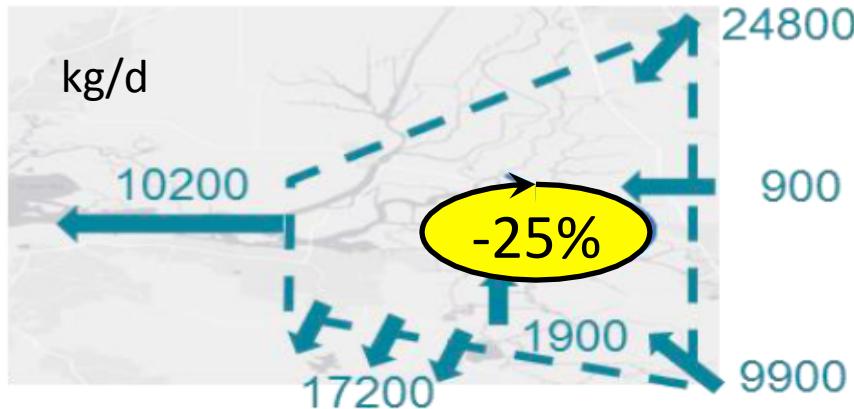
EOF = Empirical orthogonal functions

$$[\text{NH}_4_x(t)] = \text{Mean}_x + \text{amp}(t) * \text{SD}_x$$

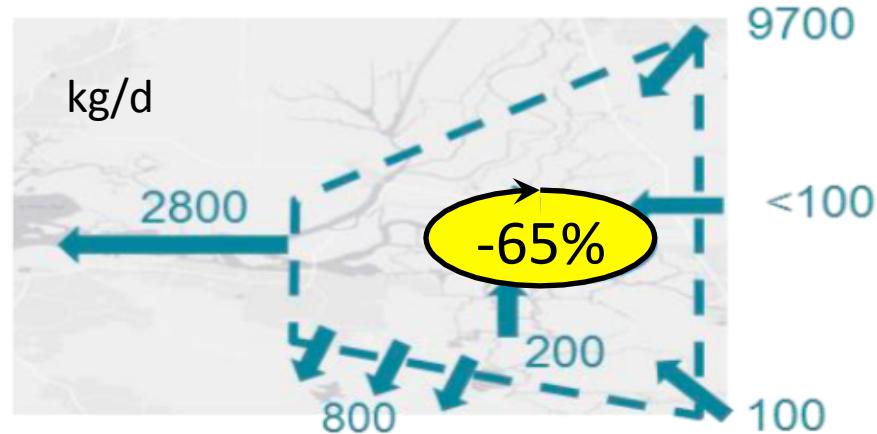
The Delta is a vigorous biogeochemical reactor

Summer Whole-Delta Mass Balances (2006-2011)

$$\text{TN} = \text{DIN} + \text{orgN}$$



NH4



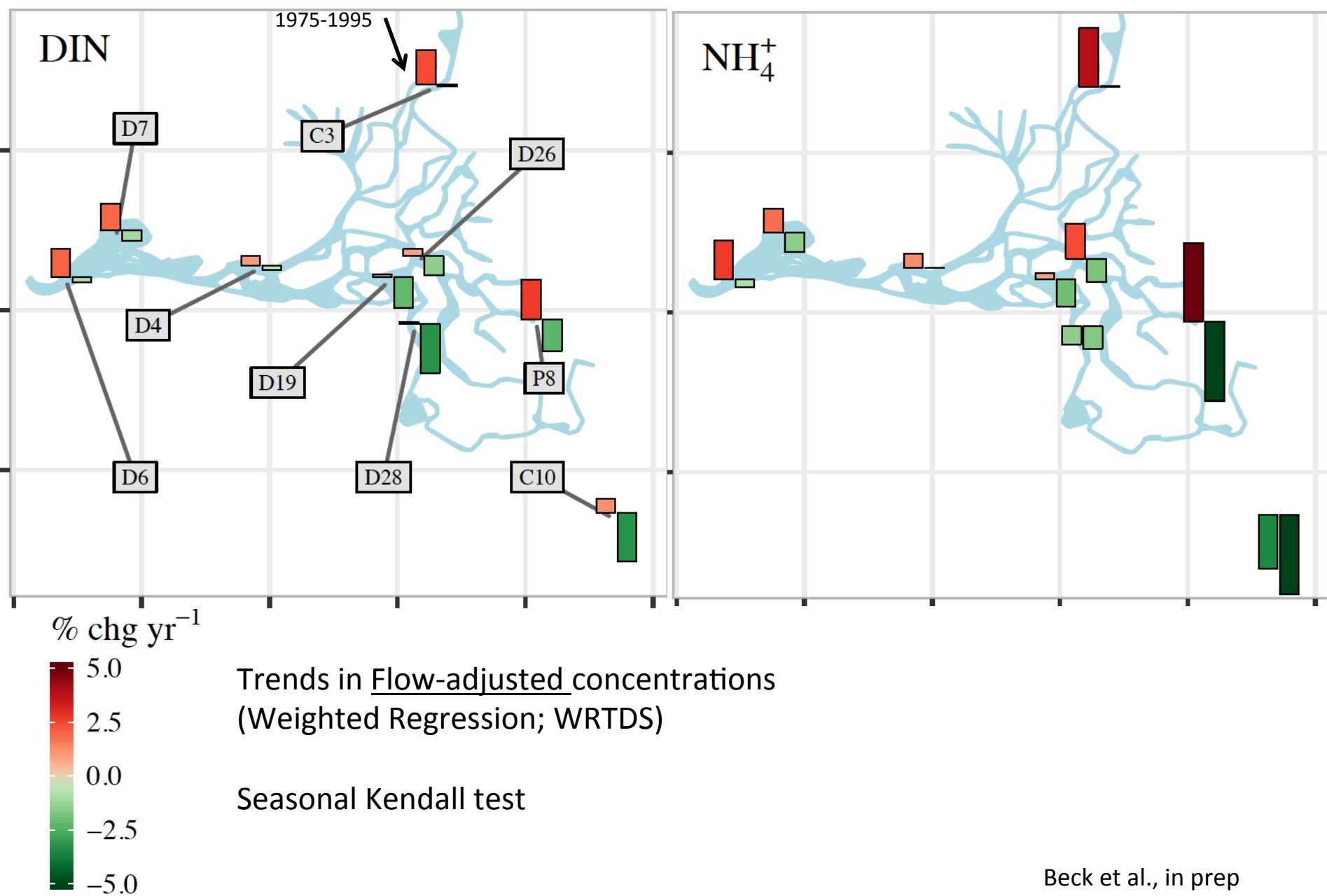
1-box

Novick et al 2015 (SFEI, 2015 #785)

Cf. Jassby and Cloern 2000

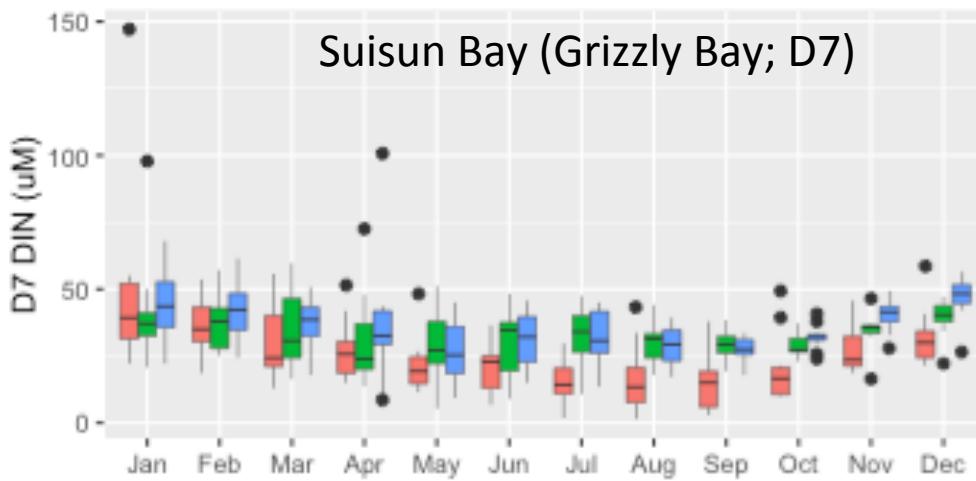
Annual (1976–1995, 1996–2014)

Example: Trends over time, DIN and NH₄⁺



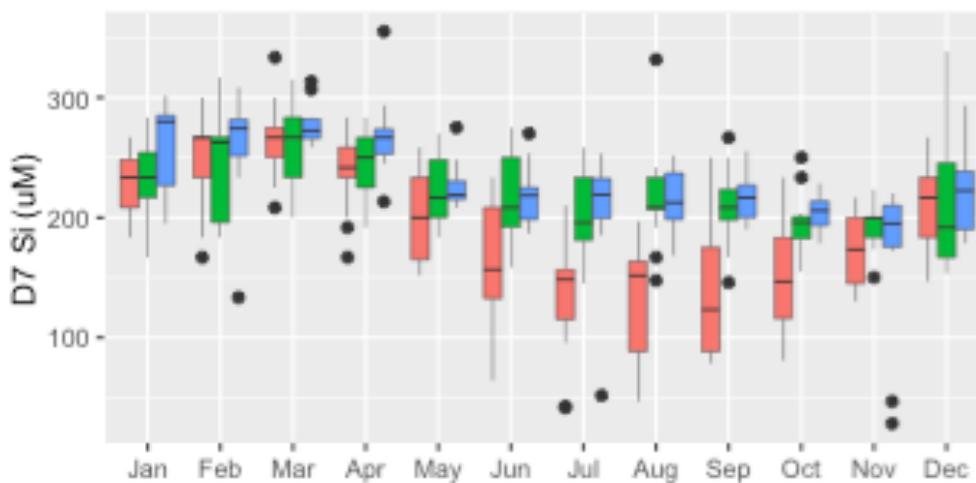
Complex system:

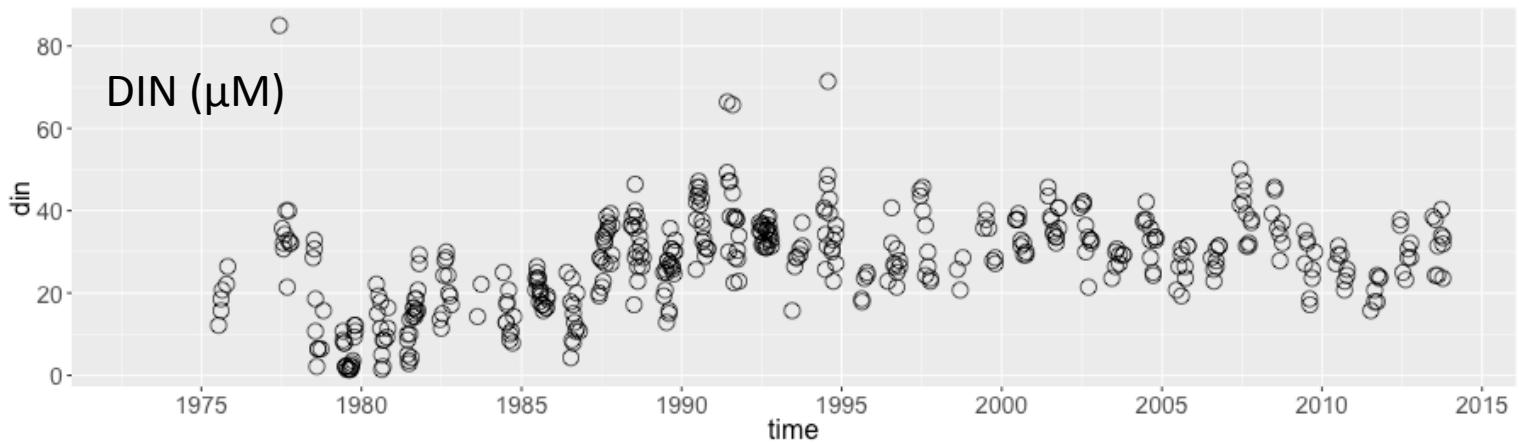
What factors contribute to changes in nutrients over time?



While we know N loads have increased over time to the SacRiver and Suisun, a substantial portion of [DIN] changes in Suisun Bay could also be due to ecosystem alterations:

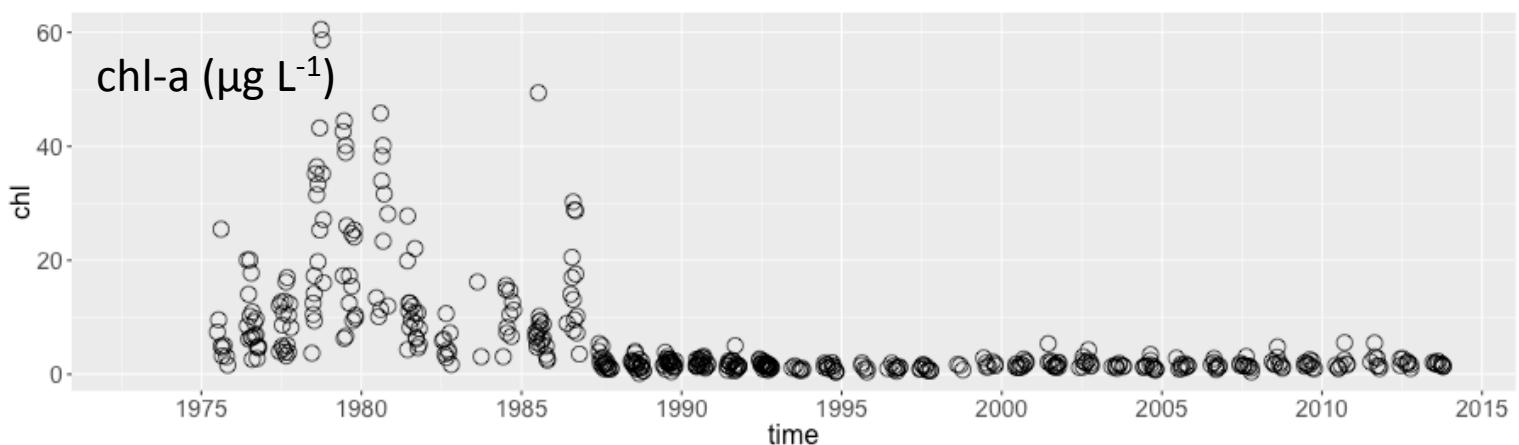
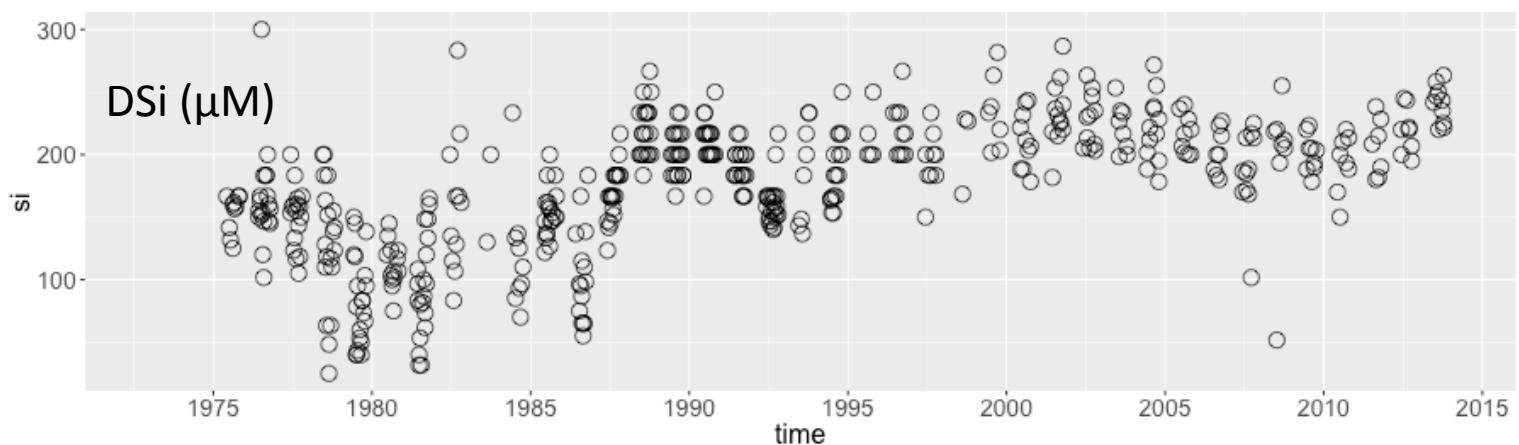
- Kimmerer (2005): In Suisun Bay, abrupt changes in DSi resulted from decreased diatom production due to invasive clam
- DIN:Si \sim 1:1 for diatom growth
- In terms of magnitude (stoichiometry) and timing, the observed [DIN] increase could also be explained by decreased diatom production.





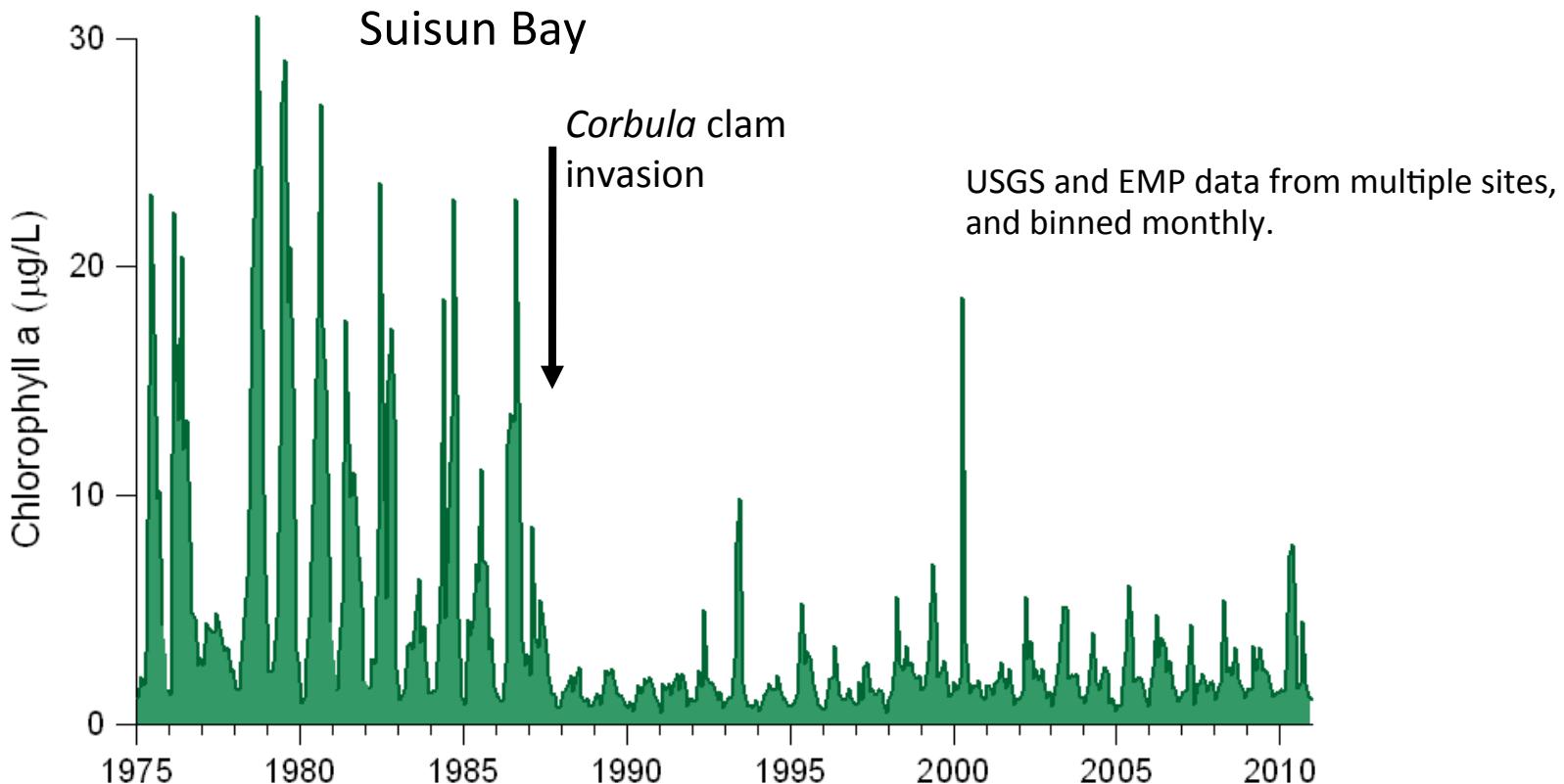
Pooled samples from
Suisun Bay
D4, D6, D7, D8
June-September

Adjusted for dilution by
using data from 'typical'
salinity ranges for Suisun
Bay: $5 \leq \text{sal} \leq 15$



- Overview of system, Background
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- Changes in phytoplankton community?

Changes in Phytoplankton Biomass



Delta:

- Also general decrease from 1975-1995, but lagging Suisun Bay
- Increase 1995-2004

See Jassby 2008 and Jassby et al 2002 for details

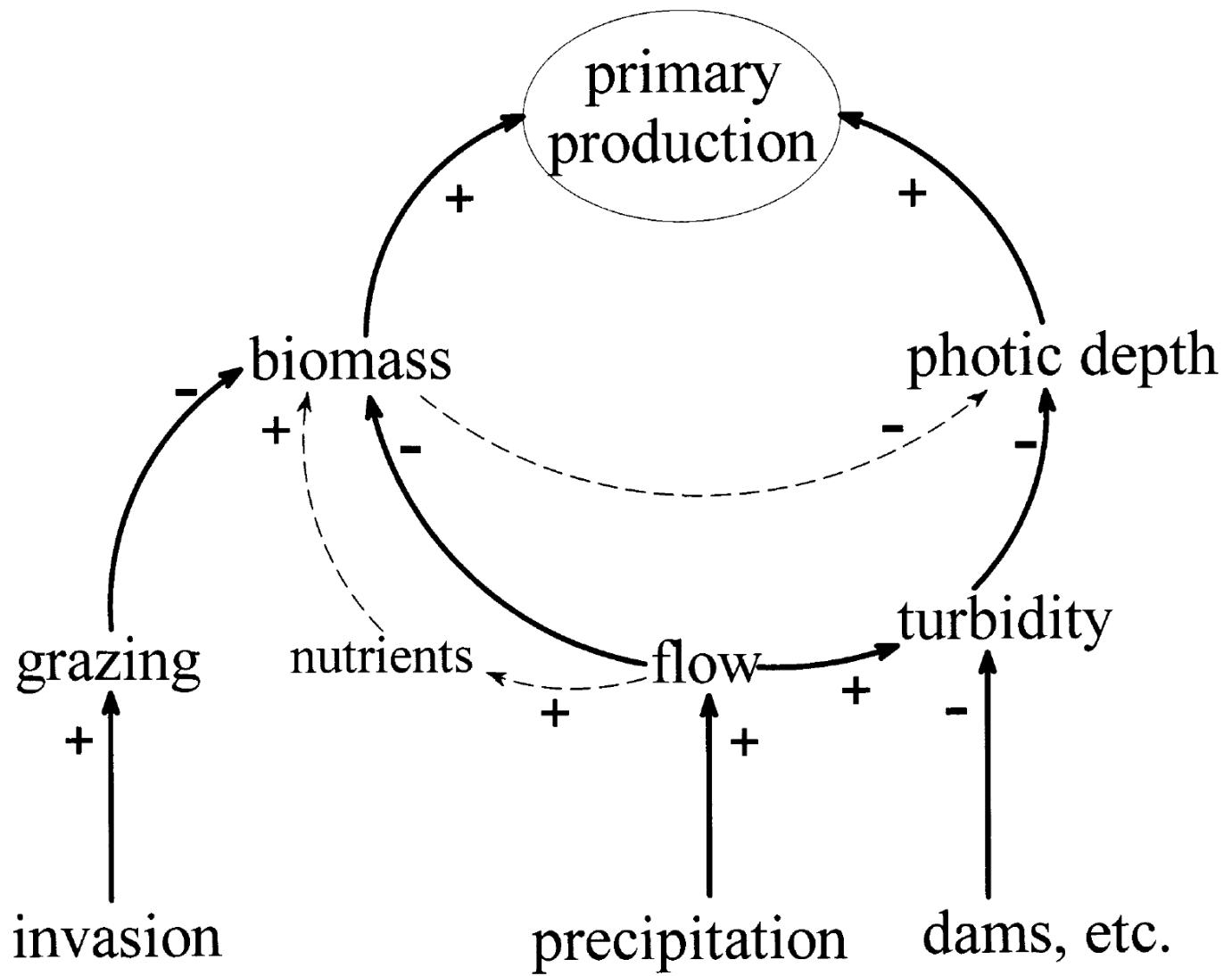
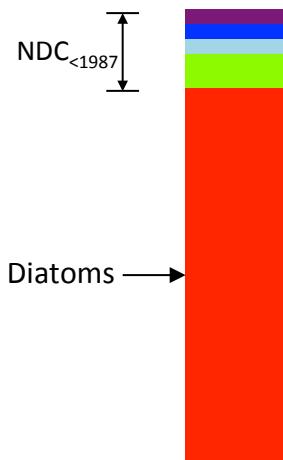


Fig. 12. Cause–effect diagram summarizing main variability mechanisms identified for Delta-wide annual primary production. Dashed lines indicate pathways missing in the Delta but present in less turbid, nutrient-limited ecosystems.

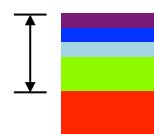
Did Phytoplankton Community Composition Shift?

Pre-1987 abundance of several major classes, in particular during seasonal (summer) blooms.

Post-1987: Examples of what a “shift” could look like



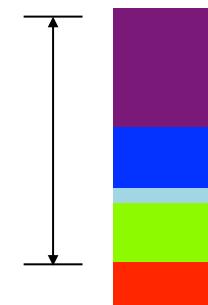
H1



H2



H3



Biovolume ($\mu\text{m}^3/\text{mL}$)
or
Density (cells/mL)

- Near-complete loss of diatoms
- $NDC_{<1987} \sim NDC_{>1987}$

- Substantial, near-proportional loss of all classes

- Near-complete loss of diatoms
- Substantial NDC change

$NDC =$ Non-diatom composition; e.g., chlorophytes, cryptophytes, flagellates, cyanobacteria

H1, H2, H3: Hypothesis 1, 2, and 3

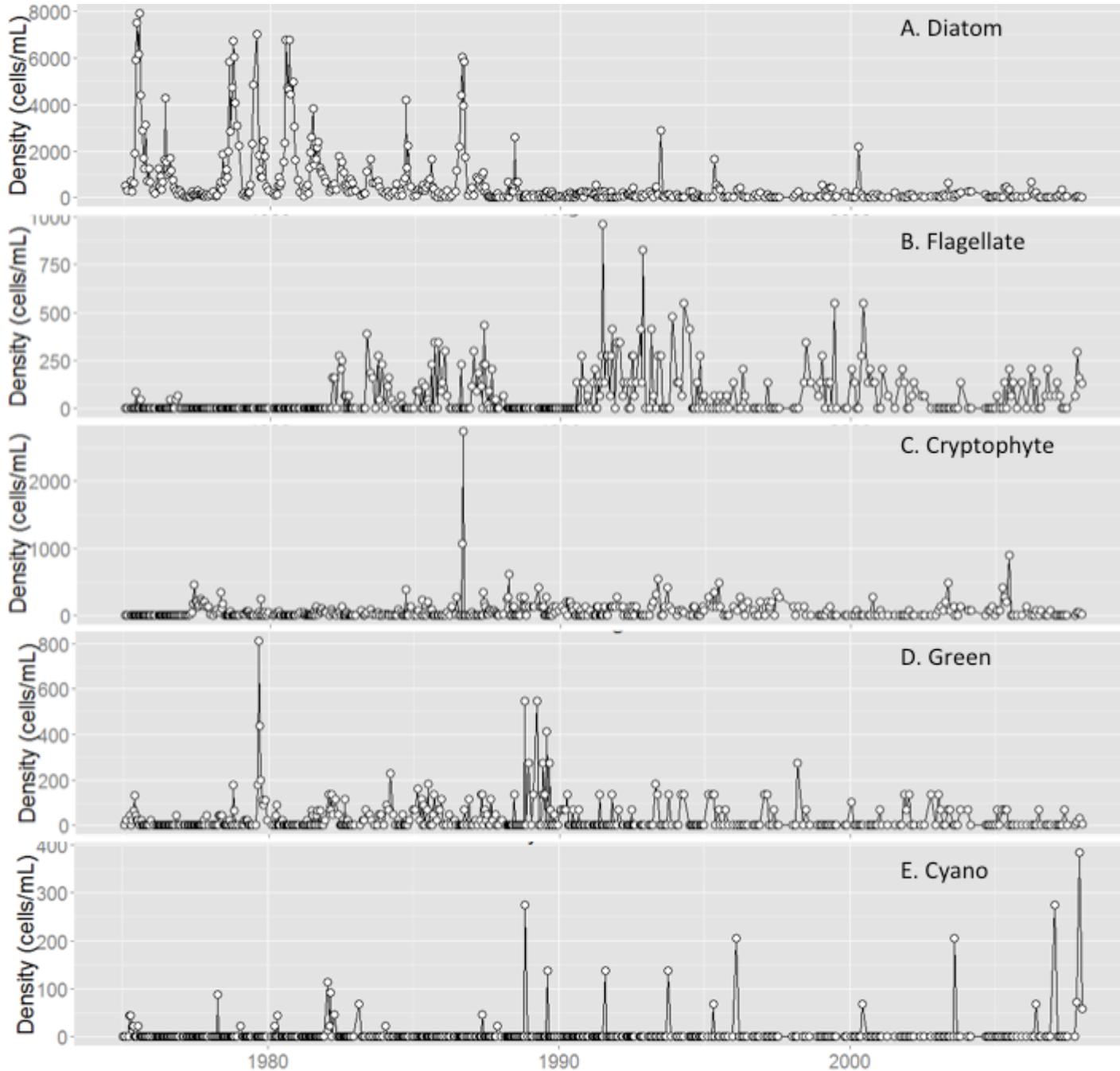


Figure 4 Reported phytoplankton densities at D7 (Suisun Bay, Grizzly Bay) for five phytoplankton classes. Densities were provided as a pre-calculated field in the DWR downloadable dataset, and are the same values used in prior studies that have suggested community composition shifts.

- Very low cell counts, especially after 1988
- Method change in 1988 – artifact ?

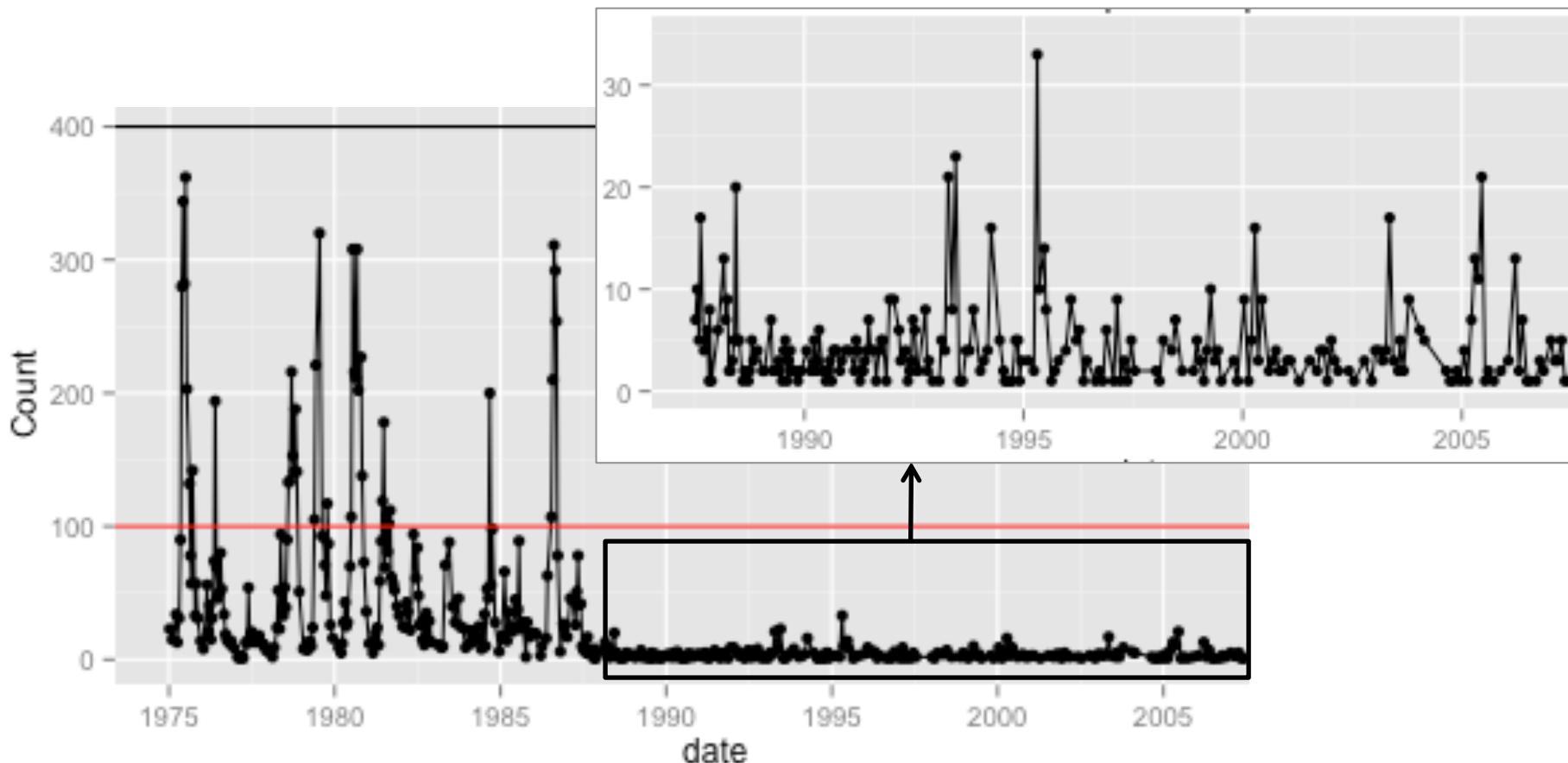


Figure 6 Total number of cell enumerated by microscopy at the Suisun Bay stations D7: 1975-2007. The black horizontal line at 400 counts denotes the recommended minimum number of counts for the most abundant taxa to yield $\pm 10\%$ uncertainty

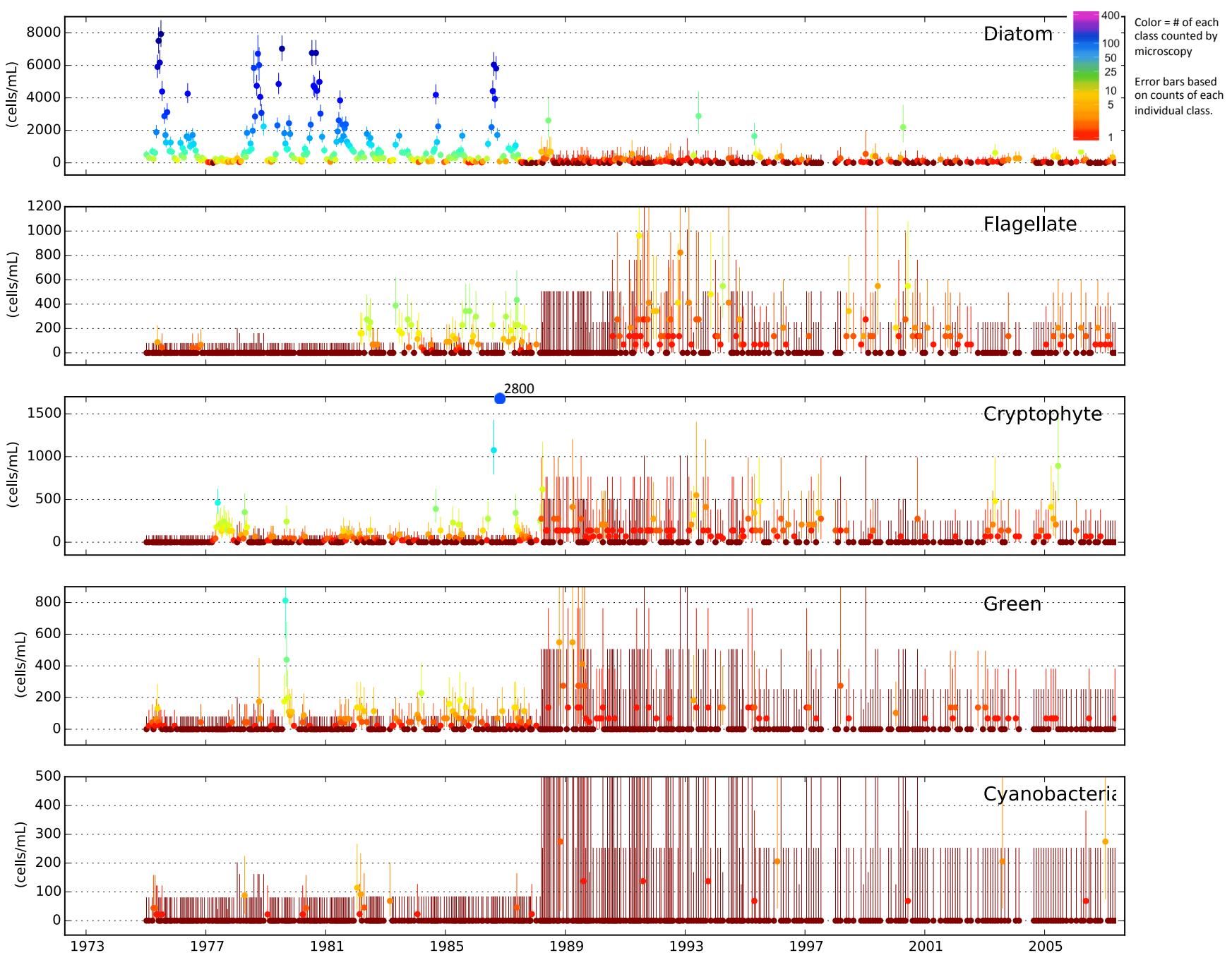


Figure 7 D7 densities data presented again (same as Figure 4) with confidence intervals computed based on maximum likelihood and a Poisson distribution. Color indicates the number of cells counted.

Summary

- Large nutrient inputs, Elevated N and P concentrations
 - generally $\gg K_s$
- Abundant long-term data on nutrients and bulk phytoplankton biomass
- Delta vigorous biogeochemical reactor...
 - Strong seasonal transformations; moderate overall removal
- Complex system...numerous factors influence observed concentrations: some clear trends, others difficult to detect
- Major changes in chl-a throughout the system
 - Abrupt decreases in Suisun Bay in 1987, coincident with invasive clam.
 - Declines in Delta, too, but lagging Suisun Bay by several years
- Phytoplankton community data pre-2007: severe data quality issues.
- Coupled hydrodynamic-biogeochemical models needed